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June 22, 2010

- Collect, organize, and analyze large amounts of data for numerous operational photovoltaic systems
- Implement an efficient tool for data collection and organization
- Example:
 - A large utility-sized photovoltaic generating facility can be composed of thousands of modules and infrastructure components
 - To estimate reliability & availability, times for all failed components (times-to-failure), times of replaced/repared components (new commissioning times), and all components without failure (times-to-suspension) must be tracked

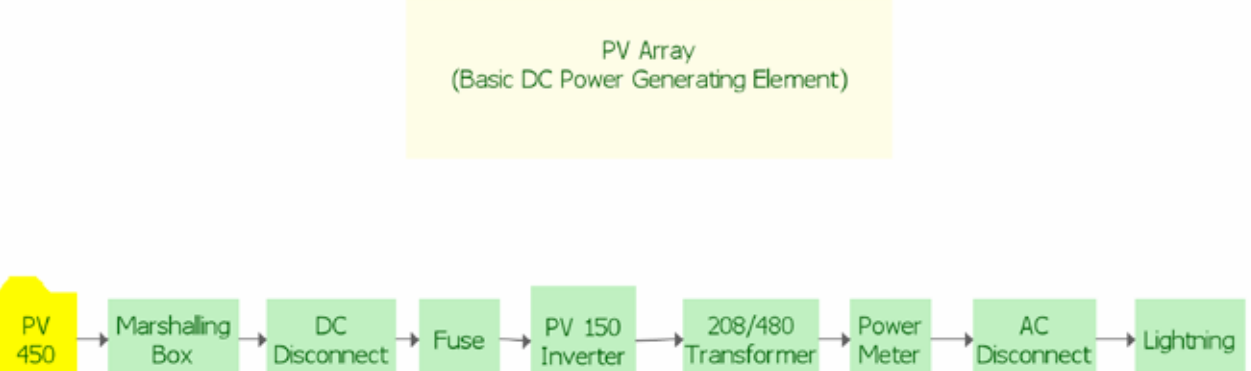
- **Data collected from an operating system is censored data**
 - Not all components have failures, a mixture of failures and suspensions (right censored data)
 - Exact time to failure for some components may not be known (interval or left censored data)
- **Minimum Data Required for Photovoltaic Generating Systems**
 - Times to failure or times to suspension for all components
 - All sources of downtimes
 - Restoration times for all repairs/replacement
 - Preventive maintenance times
 - Upgrades
 - Inspections
 - External effects on system
 - Grid perturbations
 - Lightning strikes
 - Other environmental effects

[illegible]

- XFRACAS™ is a web-based application that provides the capability for point of source data entry into a centralized data base.
- XFRACAS™ is primarily intended for managing a failure reporting and corrective action process.
- With some slight modifications, XFRACAS™ is capable of exporting data from the database that is properly organized and formatted for analysis by the life data analysis or reliability growth analysis tools.

Data Collection Tool Characteristic	Capability Present in XFRACAS	User Mod to XFRACAS	Comments
Handle multiple system & component populations	X		Passwords and permissions protect proprietary information
Contain customizable query and sort features	X		User configurable
Handle both legacy and real-time data entry	X		
Discriminate independent vs. dependent failures at all levels	X		
Keep track of restoration times	X		
Keep track of retired & replaced components	X		
Export data as "organization for analysis" format into reliability & availability tools		X	Downtime and subsystem reliability growth analyses require custom SQL queries and postprocessing in Excel
Offer "intuitive" user-friendly interface		X	User-specific operating instructions are needed

- Create a serialized bill of material *consistent with* system reliability block diagram
- User-configure data import template
- Populate template with field data
- Import template into XFRACAS™



Serialized BOM for one of 26 SGSSS arrays (Display of XFRACAS™ Parts Import Template)

Line	Part	Part Description	Part Number	Stock	Quantity	Unit Price	Sub Price	Category	Manufacturing Cost
1	565855	5000 Low Voltage	565855	1	1	1000.0000			
2	755	5000 Low Voltage	5000-2	0	1	1000.0000			
3	755	5000 Low Voltage	5000-3	0	1	1000.0000			
4	495	5000 Low Voltage	5000-1	1	1	1000.0000			
5	495	5000 Low Voltage	5000-1	1	1	1000.0000			
6	495	5000 Low Voltage	5000-1	1	1	1000.0000			
7	495	5000 Low Voltage	5000-1	1	1	1000.0000			
8	495	5000 Low Voltage	5000-1	1	1	1000.0000			
9	495	5000 Low Voltage	5000-1	1	1	1000.0000			
10	495	5000 Low Voltage	5000-1	1	1	1000.0000			
11	495	5000 Low Voltage	5000-1	1	1	1000.0000			
12	495	5000 Low Voltage	5000-1	1	1	1000.0000			
13	495	5000 Low Voltage	5000-1	1	1	1000.0000			
14	495	5000 Low Voltage	5000-1	1	1	1000.0000			
15	495	5000 Low Voltage	5000-1	1	1	1000.0000			
16	495	5000 Low Voltage	5000-1	1	1	1000.0000			
17	495	5000 Low Voltage	5000-1	1	1	1000.0000			
18	495	5000 Low Voltage	5000-1	1	1	1000.0000			
19	495	5000 Low Voltage	5000-1	1	1	1000.0000			
20	495	5000 Low Voltage	5000-1	1	1	1000.0000			
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41	495	5000 Low Voltage	5000-1	1	1	1000.0000			
42	495	5000 Low Voltage	5000-1	1	1	1000.0000			
43	495	5000 Low Voltage	5000-1	1	1	1000.0000			
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48	495	5000 Low Voltage	5000-1	1	1	1000.0000			
49	495	5000 Low Voltage	5000-1	1	1	1000.0000			
50	495	5000 Low Voltage	5000-1	1	1	1000.0000			

Data Item	Reliability	Availability	TP	Logs
Incident Occurrence Date/Time	x	x	x	x
Bill of Material Part Number	x	x		x
Part Serial Number	x	x		
Part Commissioning Date	x	x	x	x
Incident Description	x	x		x
Incident Category	x	x	x	x
Service Response Date/Time				
Service Completion Date/Time	x			
Restoration to Duty Date/Time				x
Energy Lost (kWh)	x	x		x

- Process is incident entry driven
- Information collected is identical for legacy and real-time entries (However, legacy data may be incomplete)
- Incidents are classified according to the source of the problem
- Incidents are classified into categories as chargeable or non-chargeable
- Failure types are required for each incident and are similarly classified

- Incident Categories
 - Chargeable
 - Hardware Failure
 - Software Problem
 - Hardware Upgrade Required to Operate
 - Software Upgrade Required to Operate
 - Equipment Installation Problem
 - Hardware Application Problem
 - Software Application Problem
 - Unknown
 - Non-Chargeable
 - Hardware Upgrade
 - Software Upgrade
 - Preventative Maintenance
 - Troubleshooting Issue
 - System Upgrade
 - End of Useful Life Failure
 - Grid-induced Failure/Suspension
 - Environment-induced Failure/Suspension
 - Vandalism

- **Failure Types**
 - **Chargeable**
 - Primary Failure
 - **Non-Chargeable**
 - Preventative Maintenance Suspension
 - Corrective Maintenance Suspension
 - Grid-induced Failure
 - Lightning-induced Failure
 - Other-induced Failure
 - Grid-induced Suspension
 - Lightning-induced Suspension
 - Other-induced Suspension
- **Failure is the logical AND of chargeable failure type and chargeable incident category**
- **Suspensions are all other combinations**

[illegible]

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525</
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FRACAS

Home > HomePages > CMC > Incidents > Issues > Reports > Query

Incident Wizard

Go to Step 1 of 4

Incident Wizard

Step 1 of 4: Please provide the Serial Number and Part Number

Incident Type:

Incident Account:

CMC Level 1 Part Serial Number:

CMC Level 1 Part Number:

- Reliability growth analysis
- Life data analysis
- Downtime analysis
- Reliability and availability analysis
- System simulation
- Comparisons of suppliers, operating sites, similar hardware, etc.

- Collaborated with ReliaSoft to upgrade XFRACAS™ features to export data for reliability/availability analyses.
- Successfully demonstrated import of legacy data into XFRACAS™ and export of data in analysis format to software tools, Weibull++™ and RGA™. These software tools are used to select life distributions that fit data and estimate the parameters of the distributions.
- Successfully demonstrated entry of additional real-time data into XFRACAS™ and export to analysis tools.

Categorization, interpretation, and organization of five years of The Springfield operational data for analysis by hand required six months. The automated data entry, categorization, and organization for analysis by XFRACAS™ should increase efficiency and the accuracy of analysis results.

- Sandia's DOE Photovoltaic Reliability Program is interested in partnering with Renewable Energy manufacturers, installers and operators to develop baseline reliability data for Photovoltaic components.
- A single database like XFRACAS™ could support a life cycle approach for managing conceptual development through retirement of fielded PV systems by recording and tracking:
 - Design iterations and upgrades
 - Review boards
 - Failure analyses
 - Corrective actions
 - Field operations
 - Test results
 - Data for reliability growth and system availability predictions
- Integration of a reliability and availability model with a model of variations in solar irradiance due to factors such as weather, seasons, and geography and a model of module performance into a higher level simulation model can be used to predict the yearly kWh output of a photovoltaic

- Sandia acknowledges the support of the DOE Solar Energy Technologies Program who funded this work.
- We wish to acknowledge Tucson Electric Power for sharing failure and maintenance data for the Springerville, AZ Photovoltaic Generating Facility. Also, we thank Tom Hansen and Kaleb Brimhall who assisted in interpretation of the data logs. This work would not have been possible without this valuable information.
- ReliaSoft reliability analysis commercial software was used for modeling and data analysis.

- [1] Moore, L. M. and Post, H. N., "Five Years of Operating Experience at a Large, Utility-Scale Photovoltaic Generating Plant", Progress in Photovoltaics: Research and Applications, 2007.
- [2] Elmer Collins, Michael Dvorack, Jeff Mahn, Michael Mundt, and Michael Quintana, "Reliability and Availability Analysis of a Fielded Photovoltaic System", presented at the 34th IEEE Photovoltaic Specialist Conference, June 2009.
- [3] Online reliability references for XFRACAS™, life data analysis, repairable systems analysis, and system analysis <http://www.weibull.com/>